A COMPARATIVE STUDY OF ROOT AND STEM WOODS OF SOME MEMBERS OF THE MIMOSOIDEAE (LEGUMINOSAE)

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A comparative study of the root and stem woods of 11 members of the Mimosoideae revealed that the two woods were more alike than had been thought. The only feature of consistent difference was the presence of a greater amount of thinner-walled elements in root wood than in stem wood.

Although structural variation in stem wood has been studied in several arborescent plants, so far less attention has been paid to root wood (Fayle, 1968). This has mainly been due to the assumptions that the structure of root wood is similar to that of stem wood and that root wood has only slight economic importance. It has also been due to the difficulties in procuring authentic root-wood samples (Cutler, 1976). We therefore undertook this comparative study on root and stem woods. We chose subfamily Mimosoideae for investigation not only because of the easy availability of specimens but also because of the lack of study on its root wood.

MATERIALS AND METHODS

Eleven species of Mimosoideae were selected for the study: *Acacia arabica, Acacia auriculiformis, Acacia leucophloea, Adenanthera pavonina, Albizzia amara, Albizzia lebbeck, Dichrostachys cinerea, Enterolobium saman, Leucaena leucocephala, Pithecellobium dulce,* and *Prosopis spicigera.* Wood samples were collected at chest height from the main stem and from the strong, laterally spreading roots at 0.5–1 m below soil level. The collected samples were trimmed to 1 cm^3 in such a way as to include both heartwood and sapwood, and as many growth rings (if present) as possible. Transverse, radial-longitudinal, and tangential-longitudinal sections were taken using a Bright cryostat microtome at a thickness ranging from 15 to 30 μm. The wood was pretreated in boiling water, 10 percent hydrofluoric acid, or a glycerine-alcohol mixture singly or in combination if there was difficulty in sectioning the wood. Sections were stained with safranin alone or with safranin and Delafield's haematoxylin. In addition, macerations of the wood were prepared using Jeffrey's fluid (Johansen, 1940); the macerated elements were also stained with safranin. For all features recorded, 100 random measurements were made. Sample size was accounted for using Student's t test, and levels of significance were calculated

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Comparison of root and stem woods of the taxa of Mimosoideae investigated.

SPECIES		CHARACTER*																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Acacia arabica Willd.	R	A	Dp	15	145	315	20	Ac, Cp	22	Ho	370	35	20	10	L, Sp, St	1430	(-)	680	48
	S	D (IP)	Dp	10	145	300	20	V, Ac, R, Cp	23	Ho	340	35	30	10	L, Sp, St	1200	(-)	690	47
Acacia auriculiformis A. Cunn. ex Bentham	R	A	Dp	20	75	270	4	Ac, Cp	25	Ho	125	15	70	4	L, Sp	825	(-)	-	67
	S	D (CF,IP)	Dp	20	110	280	12	Ac, R, Cp	12	Ho	130	20	65	8	L	730	-	-	68
Acacia leucophloea Willd.	R	A	Dp	10	270	450	28	Ac, Cp	47	Ho	365	35	25	10	L	1655	-	-	15
	S	A	Dp	10	130	290	11	Ac, Cp	33	Ho	330	30	45	9	L	1310	-	-	47
Adenanthera pavonina L.	R	A	Dp	10	180	780	10	V, Ac, Cp	30	Ho	395	30	30	13	L, St	1255	-	(-)	47
	S	D (CF)	Dp	10	130	510	9	V, Ac, Cp	26	Ho	305	30	40	15	L, St	1450	-	645	50
Albizzia amara Boivin	R	D (CF)	Dp	6	165	330	7	Ac, R, Cp	22	Ho	180	15	35	4	L, Sp	1070	1140	(-)	67
	S	D (CF)	Dp	6	140	300	10	Ac, Cp	16	Ho	230	15	60	12	L, Sp, St	1130	1150	670	62
Albizzia lebbeck Bentham	R	A	Dp	5	95	210	2	Ac, Ap, Cp	7	Ho	260	70	25	23	L, Sp, St	705	1075	520	68
	S	A	Dp	5	110	240	7	V, Ac, Cp	15	Ho	250	50	45	19	L, Sp, St	1085	1075	(-)	59
Dichrostachys cinerea Wight & Arn.	R	D (CF)	Dp	20	110	210	5	V, Ac, R, Cp	8	Ho	160	30	80	5	L	955	-	-	82
	S	D (CF)	Dp	20	100	230	8	V, Ac, R, Cp	9	Ho	220	30	50	17	L	960	-	-	76
Enterolobium saman (Jacq.) Prain	R	I (IP)	Dp	10	130	240	16	Ac, Cp	20	Ho	190	30	140	12	L, Sp, St	900	(-)	595	52
	S	I (CF)	Dp	10	125	335	10	Ac, Cp	10	Ho	140	15	65	15	L	805	-	-	65

Leucaena leucocephala (Lam.) De Wit	R	D (CF)	Dp	10	100	330	12	Ac, Cp	21	Ho	260	35	40	7	L, Sp, St	1105	950	(-)	60
	S	D (CF,IP)	Dp	10	160	230	15	Ac, R, Cp	23	Ho	295	20	30	6	L	840	-	-	56
Pithecellobium dulce Bentham	R	I (IP)	Dp	10	90	420	7	V, Ac, Cp	22	Ho	270	40	30	13	L, Sp	1180	1270	-	58
	S	D (CF,IP)	Dp	12	140	435	17	Ac, Cp	11	Ho	210	25	60	8	L, Sp, St	1090	935	(-)	64
Prosopis spicigera L.	R	A	Dp	14	130	295	13	Ac, Cp	20	Ho	295	20	63	12	L, Sp	795	(-)	-	55
	S	A	Dp	13	130	225	15	Ac, Cp	30	Ho	315	30	68	10	L, Sp	905	(-)	-	45

*Key to characters:

1. Portion of plant where wood samples taken: R = root, S = stem.
2. Growth rings: A = absent, D = distinct, I = indistinct, CF = marked by compressed late-wood fibers, IP = marked by initial parenchyma.
3. Porosity: Dp = diffuse porous.
4. Mean number of vessels per mm^2 in transection.
5. Mean vessel diameter (µm).
6. Mean vessel-element length (µm).
7. Percentage of area of transection occupied by vessels.
8. Nature of parenchyma: Ac = aliform confluent, Ap = apotracheal diffuse, Cp = compartmented crystal, R = restricted to side facing periphery of wood, V = vasicentric.
9. Percentage of area of transection occupied by parenchyma.
10. Nature of rays: Ho = homogeneous.
11. Mean height of rays in tangential-longitudinal section (µm).
12. Mean width of rays in tangential-longitudinal section (µm).
13. Mean abundance of rays per mm^2 in tangential-longitudinal section.
14. Percentage of area of transection occupied by rays.
15. Type of fibers: L = libriform, Sp = septate, St = substitute (predominant type underlined).
16. Mean length of libriform fibers (µm).
17. Mean length of septate fibers (µm); - = absent, (-) = data unavailable due to rarity of fibers.
18. Mean length of substitute fibers (µm).
19. Percentage of area of transection occupied by fibers.

for $P = 0.01$ and 0.05. Microphotographs were taken with a Nikon Labophot microscope. Terminology is in accordance with the IAWA Multilingual Glossary (International Association of Wood Anatomists, 1964).

OBSERVATIONS AND DISCUSSION

The TABLE provides the data on all qualitative and quantitative features of the root and stem woods.

GROWTH RINGS

Although variability in growth rings has been studied in detail (Carlquist, 1980), the degree of expression of the ring within the stem and root woods of the same plant has not yet been adequately investigated. Fayle's (1968) statement that growth-ring boundaries are better marked in the stem than in the root is supported by Cutler (1976), Fahn (1982), and Zimmermann and Brown (1971). This is the case in four of the eleven species we studied (*Acacia arabica, Acacia auriculiformis, Adenanthera pavonina,* and *Pithecellobium dulce*) but not for *Albizzia amara, Dichrostachys cinerea, Enterolobium saman,* or *Leucaena leucocephala*; growth rings were absent in the other three species investigated (*Acacia leucophloea, Albizzia lebbeck,* and *Prosopis spicigera*). The presence of growth rings and the degree of their distinction have been reported to be highly variable even in the stem woods of the Mimosoideae (Ramesh Rao & Purkayastha, 1972). In other words, the degree of distinction shown by growth rings may not be directly related to the organ in which the growth ring is present. The reason for this variability is difficult to explain since several intrinsic and extrinsic factors (such as hormone levels, availability of carbohydrates, climatic factors, and soil moisture) appear to control the expression of growth rings.

It is generally believed that the feature or features marking the growth ring are specific for each plant, irrespective of the organ (see Carlquist, 1980). Although this was true of *Albizzia amara* and *Dichrostachys cinerea,* where compressed late-wood fibers marked the growth ring in both stem and root woods, it was not true of other taxa, in which the growth rings of stem and root woods were marked by quite different features (see TABLE).

VESSEL AND VESSEL ELEMENTS

Root wood has been reported to have a greater abundance of vessels and vessel multiples per unit area than stem wood (Carlquist, 1978; Carlquist *et al.*, 1983; Gómez-Vázquez & Engleman, 1983). Fayle's (1968) results, however, did not agree with this (see also Zimmermann & Brown, 1971). Cutler (1976), in discussing the subject, cautioned that further research was necessary before specific conclusions could be drawn. He made this statement because in his study of *Acer* stem and root woods, he found certain samples of root wood to have more abundant vessels than stem wood, while one sample showed no difference in quantity. In nine of the 11 taxa we investigated, pore abundance

was the same in both root and stem woods. Only in *Acacia arabica* and *Pithecellobium dulce* was there a difference at the 1 percent level of significance; in the former abundance was greater in the root wood, while in the latter the contrary was true.

Pore Diameter

Presence of wider pores in root wood has been considered to be the most consistent distinction between root and stem woods (Bhat, 1982; Carlquist, 1975, 1977, 1978; Chalk, 1983; Fahn, 1982; Fayle, 1968; Gómez-Vázquez & Engleman, 1983; Plank, 1976; Zimmermann & Brown, 1971; Zimmermann & Potter, 1982). Cutler (1976) was cautious enough to state that further research into this matter was warranted in view of the number of exceptions to the above observation. In the individuals we studied there was no significant difference even at the 5 percent level in mean pore diameter of stem and root woods of *Acacia arabica, Enterolobium saman,* or *Prosopis spicigera.* The difference was significant at both levels in the rest of the species, with greater diameter being exhibited by the stem-wood vessel elements in *Acacia auriculiformis, Albizzia lebbeck, Leucaena leucocephala,* and *Pithecellobium dulce* and by the root-wood vessel elements of the other four species. Thus, mean pore diameter does not appear to be a feature of consistent difference between root and stem woods.

Vessel-Element Length

Whether the length of vessel elements depends upon the organ is a question often debated in the literature. Carlquist (1976) believed that the elements were longer in root wood than in stem wood. This opinion was also held by Fayle (1968), Plank (1976), and Zimmermann and Potter (1982). The data obtained in the present study revealed that longer vessel elements were present in the root wood of *Acacia leucophloea, Leucaena leucocephala,* and *Prosopis spicigera,* but in the stem wood of *Adenanthera pavonina* and *Enterolobium saman.* In all of the above, the difference in length was significant at the 1 percent level. In *Albizzia lebbeck* the stem wood had longer elements, but the difference was significant only at the 5 percent level. In *Acacia arabica, Acacia auriculiformis, Albizzia amara, Dichrostachys cinerea,* and *Pithecellobium dulce* there was no significant difference in length of vessel elements between root and stem woods. We therefore inferred that vessel-element length has no correlation with the organ of the plant in which it occurs, at least in the plants we investigated. Indeed, Carlquist (1976) himself recorded longer vessel elements in the stem woods of *Grubbia rourkei* Carlq.

There was no difference between root and stem woods in qualitative features such as vessel-element pitting, type of perforation, type of axial parenchyma, nature of the ray, or type of fibers. We could not confirm the earlier reports (Lebedenko, 1961, 1962; Patel, 1965; Shimaji, 1962; see also Cutler, 1976) that xylem rays of certain plants tend to be heterogeneous in root wood but homogeneous in stem wood.

AMOUNT OF PARENCHYMATOUS ELEMENTS

The amount of parenchymatous tissue present was considered by some earlier workers to be a consistent difference between root and stem woods, with the root wood tending to be more parenchymatous than the stem wood (Chalk, 1983; Esau, 1965; Fahn, 1982; Fayle, 1968; Lebedenko, 1959, 1961, 1962; Zimmermann & Brown, 1971). However, it is not very clear whether the increase is due to axial parenchyma content, ray content, or both. With respect to rays alone, root wood was reported to have more ray content than stem wood. This may be due to the presence of broader rays, more rays per unit area, or both. In the species we investigated, ray width in tangential-longitudinal section, calculated either in microns or in number of cells across, showed no correlation to the organ. In some taxa the root wood had broader rays, in others the stem wood did (see TABLE). With respect to ray abundance (number of rays per mm^2 in tangential-longitudinal section), there was no consistency either. Of the 11 species studied, only *Dichrostachys cinerea* and *Enterolobium saman* showed greater ray abundance in root wood.

The fibers of the root wood were very much thinner walled and contained starch grains and phenolic inclusions that were generally restricted to parenchyma in the stem wood. Therefore, it can be said that in all the taxa we studied, the root wood had more thin-walled elements than the stem wood.

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